ARMY RESEARCH LABORATORY

A Comparison of Live and Simulated Fire Soldier Shooting Performance

by David R. Scribner, Patrick H. Wiley, and William H. Harper

ARL-TR-4234 **September 2007**

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Army Research Laboratory

Aberdeen Proving Ground, MD 21005-5425

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Human Research and Engineering Directorate, ARL

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14. ABSTRACT

The use of simulation is increasing as our capabilities of producing high-fidelity virtual environments expand. This is true for marksmanship and engagement shooting trainers as well. Many marksmanship studies have used simulated fire, but not many of these simulators have been validated with a live fire comparison. The U.S. Army Research Laboratory's dismounted infantry survivability and lethality test bed (DISALT) is highly effective as a research tool because of its high-fidelity data capture and flexibility for shooting scenarios. However, no live fire validation data have been published for it. A simulated version of the outdoor small-arms experimental range at Aberdeen Proving Ground (known as M-Range) was built by the authors. A study was designed in which live fire would be compared to the simulated fire during controlled laboratory conditions with the use of DISALT. Participants were 12 U.S. Army Soldiers, military occupational specialty 11C (indirect fire dismounted infantryman). The shooting task consisted of an 18-target pop-up scenario that used olive drab green E-type silhouettes. Ranges consisted of 75-, 100-, 150-, 200-, 250-, and 300-meter targets from a kneeling foxhole-supported position. Each participant was exposed to 10 trials each of simulation and live fire, half performing simulated fire first and vice versa. Target exposure time was 3 seconds with a 3-second inter-target interval. De-militarized M16A2 rifles with iron sights outfitted with electronics were used for the simulated fire, while operational M16A2 rifles with iron sights were used with M855 ball ammunition for the live fire portion. Data collected included hit percentage, time to first shot, radial aiming error, subjective workload and stress data. All data were analyzed with a repeated measures analysis of variance. Statistical differences and non-differences in the performance and subjective data are discussed.

15. SUBJECT TERMS
DISALT; marksmanship; rifle shooting; shooting performance

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1. Introduction

The use of simulation is ever increasing as U.S. Army capabilities of producing high-fidelity virtual environments increase. This is true for marksmanship and engagement shooting trainers as well. A number of shooting simulators are available, which serve as excellent military training and experimental data collection devices.

Many studies have used simulated fire techniques, but not many of these simulator systems have been validated with live fire comparison. Several studies have recently been performed at the U.S. Army Research Laboratory (ARL), which involved live fire (Scribner & Harper, 2001; Scribner, 2002) and simulated fire (Scribner, Wiley, & Harper, 2005) shooting performance. The basic question of simulator utility arises:

"Can a simulator be used to approximate a live fire shooting task when no statistical differences are observed in shooting performance between the two systems?"

1.1 Shooting Simulators

The list of shooting simulator systems used today in the U.S. military includes the multipurpose arcade combat simulator (MACS), the Weaponeer, the engagement skills trainer (EST), and the dismounted infantry survivability and lethality test bed (DISALT). Of these, DISALT is most likely the least known system.

MACS is an arcade-style, single-screen M16 marksmanship training aid that provides the realism of firing at real-time targets and feedback using the four fundamentals of marksmanship (steadiness, aim, breathing, and trigger squeeze quality). The system offers the individual basic instruction, grouping, zero scenarios, and practice and record fire M16 ranges at various skill levels (Schroeder, 1984).

The Weaponeer is capable of simulating all the basic rifle marksmanship live fire scenarios. Immediate feedback is available for critiquing the shooter's application of the integrated act of firing, including misfire procedures and the four fundamentals of marksmanship (Schendel & Heller, 1985).

EST is an interactive video simulator designed to aid Soldiers in the development of basic marksmanship and combat engagement skills. Developed by Firearms Training Systems (FATS), the EST provides a multitude of training scenarios that include basic rifle marksmanship (qualification range), vehicular ambush, squad tactical training, military operations urban terrain, and various law enforcement training scenarios. The current system uses compressed air to cycle the bolt, which provides the "feel" of shooting.

DISALT was originally manufactured to serve as a U.S. Marine Corps marksmanship trainer for ship-borne operations; however, it is highly effective as a research tool because of its high-fidelity data-capturing capability and flexibility in providing many types of target and three-dimensional environment shooting scenarios. DISALT provides a high-fidelity recoil system through the use of a cable attached to the upper rear stock of the weapon. The cable imparts an impulse similar to the 5.56-mm round fired and lifts the muzzle of the weapon in a similar fashion to the real M16 and M4 family of combat rifles.

ARL’s Human Research and Engineering Directorate leads the Army’s effort in studying shooting performance with small arms systems. The Warrior Performance Research Team of the Dismounted Warrior Branch has a newly acquired small arms shooting simulation facility that uses a two-lane DISALT system (see figure 1).

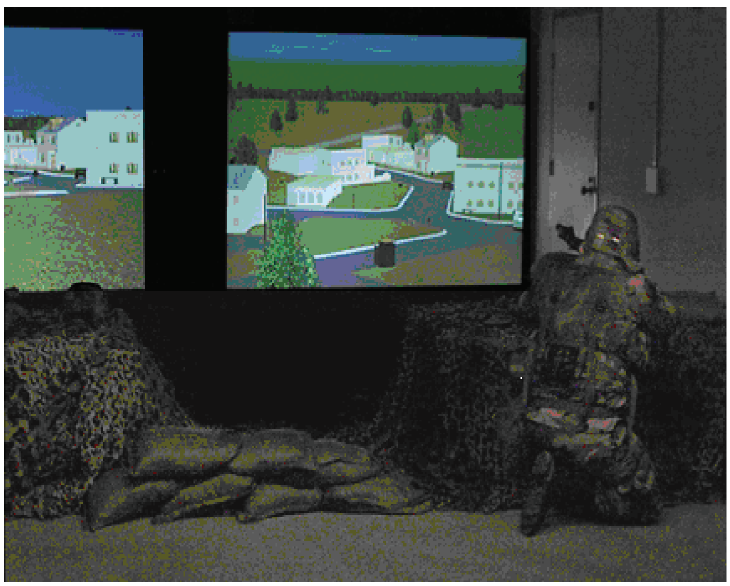

Figure 1. Two-lane DISALT shooting simulator.

DISALT provides the use of a varied target set, which includes e-silhouette pop-up targets and fully animated enemy Soldiers with weapons and a mix of enemy and civilians on the battlefield. This gives a capability for complex mixes of enemy and non-combatants for realistic shoot/do-not-shoot scenarios.

The authors built customized environments for the simulator to include the first experimental environment built for research, namely, the simulated outdoor small-arms experimental range or M-Range as it is called locally at Aberdeen Proving Ground (APG) (see figure 2).

The apparent sizes of targets for all distances and positions were matched to those of the real targets. Angles of incidence to each target were also duplicated to assure that psychomotor workload was the same to align a weapon with all targets. The live fire target data of perceptual target angles and apparent sizes were calculated from the appropriate foxhole eye height and head

position. These measurements were compared to simulated targets from the corresponding head position and average eye height. These angles were equal as measured to an accuracy of 0.25 degree. The authors verified the visual angles to targets and apparent size of e-silhouettes in the DISALT. The visual angle of a live target, center at 50 meters (1968.50 inches) was 1.16 degrees. The live target e-silhouette is 40 inches tall by 20 inches wide. The arc tangent (height of target/distance to target) was calculated to be 1.16 degrees. The apparent size of the 50-meter center target from the eye placement point in the DISALT simulation was 1.06 degrees. This was derived from a target height measurement (at the viewing screen) of 3.81 inches with a viewing distance of 205.75 inches. A scaling factor of 9.73% was used to re-size the virtual targets to match the visual angle of 1.16 degrees at 50 meters. This was performed for all target distances, giving the most accurate representation of apparent target width and height in the DISALT simulator.

Figure 2. Live and virtual representations of M range.

1.2 Simulators and Marksmanship Training

Some researchers state that live fire is a better way to spend Soldier training dollars instead of simulator training with the Weaponeer. Chenoweth (1991) reviewed some training routines for marksmanship. Chenoweth suggests that more live fire be taught to the point of sacrificing time on the Weaponeer and that the money would be better spent on live ammunition.

However, some studies do not purport live fire as the method to achieve the best marksmanship scores. Most of the studies involving shooting performance by Johnson and McMenemy (1989), Johnson (1995), and Johnson and Merullo (1996) at the U.S. Army Research Institute of Environmental Medicine have used the Weaponeer system. Wolf (1989) however, describes a program of instruction for basic rifle marksmanship training and suggests ways of maintaining unit effectiveness in marksmanship after formal training. He men-tions the use of the Weaponeer as an integral part of both programs. Dees, Magner, and McClusky (1971) found that a substitution for live fire (in this case, a BB gun) did not improve night record fire performance.

As far as marksmanship training versus battlefield shooting skills are concerned, Carey (1990) found that the correlation between known distance (KD) scores and pop-up target scores was only 0.2. The pop-up target test more closely simulates actual battle conditions over KD scores. Results of video firing games were moderately associated with KD scores (0.41) while dropping to a low 0.17 for pop-up target shooting.

1.3 Simulated Fire and Live Fire Performance

The Weaponeer is likely the shooting simulation that has had the widest use in the area of shooting research. Numerous studies have been performed with the Weaponeer as a shooting research platform (Schendel, 1982; Abbott, 1991; Johnson & Merullo, 1996, Johnson & McMenemy, 1989), although some studies have employed the use of the MACS (Abbott, 1991) and the EST (Hagman, 1998).

Some of this research has been performed to assess the effect of predicting record fire scores from simulator training performance (Hagman, 1998; Schendel & Heller, 1985). Schendel and Heller stated that the Weaponeer was a good predictor of record fire (live) performance when the Weaponeer shooting scenario was most difficult. Hagman (1998) performed a study to assess the relation between device-based (EST) and live fire M16A2 rifle marksmanship performance. A significant ($p < .05$) positive linear relationship between EST and record fire scores was found. A predictable EST-based tool was then developed from pooled group data to help marksmanship trainers predict the probability of individual Soldier record fire scores at the marksman, sharp-shooter, and expert levels.

Some shooting research studies have attempted to catalogue the similarities and differences in simulated and live fire shooting as well. Torre, Maxey, and Piper (1987) found significant differences between live fire and a direct fire research test bed for number of rounds fired, first round hit probability, number of rounds needed to score a hit, and first round fire time. Specifically, it was found that less time was required to fire the first shot in the simulator than for live fire and that first round hit percentage was lower for the simulator than for live fire.

The U.S. Army has invested much time and money into simulators for training its forces, and these simulator systems offer much in terms of scientific control, scenario development, and continuous operations which are not impeded by weather, safety, and range restrictions. Because these simulation systems should reflect live scenario performance, the value of validating simulator fire performance is of prime concern to ARL. Therefore, a study was designed in which live fire would be compared to the simulator fire during conditions that were controlled as much as could be. The firing scenario was identical in physical workload (slew angles to each target), the targets were of identical apparent height and width (i.e., the from the shooting position, the shooting position was kneeling supported with the use of sandbags, and an M16A2 with iron sights was used in semi-automatic mode, allowing for one shot per target. Additionally, green e-type silhouettes were used with identical 3-second exposure times and the same inter-target intervals.

An 18-target pop-up scenario was used in both shooting tasks. All 18 pop-up targets were green "E-type" silhouettes (figure 3). All targets dropped if hit.

Figure 3. E-silhouette targets.

2. Objective

The objective was to determine if differences exist between the dependent performance and subjective measures for a live versus simulated pop-up target shooting scenario with DISALT.

3. Hypotheses and Objective

1. The shooting performance in terms of hit percentage, and reaction time will be similar between live fire and simulated fire.
2. The subjective stress ratings (SRE) will be similar between live fire and simulated fire.
3. The Subjective Workload Assessment Technique (SWAT) ratings will be similar between live fire and simulated fire.
4. The radial error from center of mass for all targets will be similar between live fire and simulated fire.

4. Methods

4.1 Participants

Participants were 12 male U.S. Army Soldiers, all male, with military occupational specialty (MOS) 11C (indirect fire dismounted infantryman). All subjects met requirements for 20/30 visual acuity, and all were experienced with the M16A2 and had required minimum weapons qualification.

4.2 Apparatus

4.2.1 Volunteer Agreement Affidavit

A volunteer agreement affidavit (appendix A) was given to each test participant for review before he participated in the study. Upon reading the document, test participants were able to ask all questions concerning their participation in the study. After they agreed to participate, they signed the document.

4.2.2 Demographic Questionnaire

A demographic questionnaire (appendix B) was administered to collect age, gender, MOS, years in that MOS, experience with firearms, dominant hand, dominant eye, and most recent marksmanship qualification scores.

4.2.3 Titmus II[1] Vision Testing Device

Subjects were screened for 20/30 both-eye visual acuity, far distance with a Titmus II visual-testing device. If visual criteria were not met, they were to be excused from the study.

4.2.4 DISALT (shooting task, simulated)

This shooting task consisted of an 18-target pop-up scenario with olive drab green E-type silhouette targets. All targets were enemy. Ranges consisted of 75-, 100-, 150-, 200-, 250-, and 300-meter targets.

Target exposure time was 3 seconds with a 3-second inter-target interval. Soldiers were in a foxhole-supported kneeling position for all trials. De-militarized M16A2 rifles with iron sights and outfitted with electronics were used for this study.

4.2.5 M-Range (shooting task, live)

This shooting task consisted of an 18-target pop-up scenario with olive drab green E-type silhouettes. Ranges consisted of 75-, 100-, 150-, 200-, 250-, and 300-meter targets.

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[1]Titmus is a registered trademark of Titmus Optical.

Target exposure times were 3 seconds with 3-second inter-target intervals. Soldiers were kneeling in a foxhole (on outdoor carpet-covered tables placed in the foxhole) supported position for all trials (see figure 4). Appropriate hearing protection was worn at all times. M16A2 rifles with iron sights were used for this study. A safety briefing was given to each subject upon arrival at the M-Range facility, including the proper use of hearing protection, standing operating procedure 385-H-188 (Department of the Army, 1996).

Figure 4. Soldier in foxhole-supported firing position.

4.2.6 SWAT

The SWAT (Reid, Potter, & Bressler, 1989) was used to quantify Soldier workload ratings during various conditions. SWAT has been validated with mathematical processing tasks of various levels for workload assessment. There are three workload dimensions that SWAT captures as well as overall workload: time load, mental effort load, and psychological stress load.

The SWAT for measuring workload has both scale development and event scoring. Scale development is a card-sorting exercise conducted to determine the subjective conception of workload for each subject within the three dimensions. Event scoring is the process of recording the subject's rating for that specific task on the three load dimensions that can be collected rather quickly. A sample of the event scoring SWAT form is provided in appendix C.

4.2.7 Subjective Stress Scale (SRE)

The SRE was used for assessing Soldier global psychological stress. Fatkin, King, and Hudgens (1990) used this scale to aid in the assessment of fire fighter stress levels. The SRE consists of a numerical scale from 0 to 100 to assess a Soldier's stress at a specified point in time. An example of this form is shown in appendix D.

4.2.8 Weapons and Ammunition

Two demilitarized and electronically altered simulation M16A2 rifles with iron sights that have been configured for the DISALT were used in this study. Two other additional M16A2 rifles were used for the live fire portion of this study. M855 ball ammunition was used for all live fire rounds. The ballistics data that reside within DISALT are representative of a random sample of M855 ball ammunition ballistic paths.

4.3 Design and Analysis

4.3.1 Independent Variable

The variable manipulated in this study was the type of shooting environment: live or simulated.

4.3.2 Dependent Variables

The data collected consisted of shooting performance (hits, time to first shot, and radial aiming error from center of mass of the target). Time to first shot was logged electronically in the simulation by the time of trigger pull activation. Time to first shot for live fire was logged from the shot microphone impulse activation. Hits were logged according to hits on the target area exposed in the simulation, and placement was a ballistic calculation of rounds taken from a randomized round database in the system. Live fire hits were recorded via sound wave penetration through the plane of the target via acoustic sensors in the target. These acoustic sensors also triangulated the shot placement of the round for live fire. Also collected was subjective workload (SWAT) and stress (SRE) data.

Subjects were randomly assigned to a live-simulated or a simulated-live order of presentation. Six subjects trained and shot 10 trials in the simulation facility first. They then trained and shot 10 trials on the live fire range. The other six subjects did the opposite.

For analysis purposes, all data were analyzed with a one-way analysis of variance (ANOVA), repeated measures, to examine the effect of displays against all others.

4.4 Procedure and Methodology

All subjects reported to building 459, third floor simulation facility, at APG, or to the outdoor live firing range to begin study participation. Subjects were randomly assigned to shoot either live fire or simulated fire first. Half of the subjects trained and shot live fire scenarios first, and vice versa. As part of the pre-test procedure, participants were given a volunteer agreement affidavit, which described the study and possible risks (see appendix A). They were then

screened for visual acuity with a Titmus II vision-testing device. If visual criteria were not met, the subjects were excused from the study. Demographic data were collected, and then the test participant was asked to self-rate present baseline stress levels by using the SRE.

All Soldiers trained by shooting three, 18-target pop-up scenarios in each environment, where all targets were fired upon. Following this training, all 10 experimental trials were presented to the Soldier and were counter-balanced to minimize learning and order effects.

A minimum of six targets hit was required in each of the first three trials. All subjects met training criteria. Following each trial, each test participant's cognitive workload and stress levels were collected with SWAT and SRE (stress) data forms, respectively. Test participants were then fully de-briefed and given a point of contact to obtain individual performance or results of the study.

5. Results

No significant effects were found for target hit percentage, SWAT, or SRE. However, differences were found for both reaction time (s) and radial aiming error (cm). The ANOVA data are given in table 1.

Reaction time and radial aiming error were the only two measures to yield significant differences. Mean and other data are presented in table 2.

For those readers interested in hit percentage, shot reaction time, and radial aiming error means by distance for live fire versus simulation, these tables have been incorporated into appendices E, F, and G of this report.

Table 1. ANOVA table of dependent measures.

	Condition	**SS**	**df**	**MS**	**F**	**P**
Hit Percentage						
	Firing Condition	.06	1	.06	.047	.83
	Error	14.67	11	1.329		
Shot Reaction Time						
	Firing Condition	46.92	1	46.92	5.89	**.03**
	Error	87.69	11	7.96		
Radial Aiming Error						
	Firing Condition	608365.96	1	608365.96	42.70	**.000**
	Error	156879.58	11	14245.66		
SWAT						
	Firing Condition	487.92	1	487.92	.15	.69
	Error	33757.12	11	3068.83		
SRE						
	Firing Condition	145.70	1	145.70	.26	.61
	Error	6097.04	11	554.27		

Table 2. Statistical data during different firing conditions.

	Condition	Mean	Standard Error	Lower Boundary	Upper Boundary	Difference
Hit Percentage						
	Live	.575	.011	.554	.595	no
	Simulated	.567	.011	.546	.588	
Shot Reaction Time(s)						
	Live	2.91	.013	2.88	2.93	yes
	Simulated	3.13	.013	3.10	3.15	
Radial Aiming Error (cm)						
	Live	65.58	.125	63.12	68.04	yes
	Simulated	40.05	.110	37.89	42.20	
SWAT, workload rating (100 possible)						
	Live	29.07	1.75	25.61	32.52	no
	Simulated	26.22	1.75	22.76	29.67	
SRE, stress rating (100 possible)						
	Live	14.20	.80	12.63	15.78	no
	Simulated	12.65	.80	11.07	14.22	

6. Discussion

One of the most important aspects of comparing shooting performance between a live fire and simulated scenario is the ability to hit a target. It appears from the results that overall, there is no statistical difference in the mean of hit percentage for the DISALT compared to live fire. The self-reported workload ratings (SWAT) and stress ratings (SRE) followed the same pattern of yielding no differences.

However, there were significant differences between the live and simulated conditions for the measures of reaction time and radial error. The reaction time was significantly longer for the simulated condition (0.22 second). Additionally, the radial error was significantly lower for the simulated condition (25.53 cm). There can be many reasons for the significant differences in shot reaction time and radial aiming error. Human attributes such as rifle movement with a live weapon and rounds may change the psychological dynamic of the scenario. It is also thought that subtle changes in outdoor atmospheric conditions such as changing wind velocities, barometric pressures, and ambient temperatures may contribute to a larger ballistic error. However, the human aiming performance probably contributed to most of the differences in radial aiming error measures.

This study generally supports the notion that there is a strong relationship between the skills required to perform a basic marksmanship shooting task for both live fire and DISALT. In general, this study supports the concept that Hagman found in that there is a relationship between live fire and simulated fire. This study does not support the finding of Torre et al. (1987) that more time was required to fire a first shot in a simulated fire scenario than live fire. This study yielded the

opposite effect for the DISALT; that is, live fire yielded faster shot reaction times. Additionally, this study did not support (no difference) the Torre findings that first shot hit percentage was lower for simulation than for live fire.

7. Conclusions

Most users of simulation systems or those interested in comparisons would agree that the hit performance is the primary measure of fidelity of a shooting simulator or any real weapon system. No difference was found for this measure between the two systems. Soldiers also rated the workload and stress for both simulated and live fire conditions as equal.

The two measures that were different for each condition must be discussed. The difference in reaction time and radial error may be correlated with each other. There is no explanation at this point to describe the causal relationship of these measures to their shooting environments short of stating that the environments are different. However, differences in lighting, resolution, field of view, and depth perception are most likely the contributors to the differences of the simulator to live firing. When these factors can be nearer to reality, performances may begin to be equal in all performance measures.

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Appendix A. Volunteer Agreement Affidavit

VOLUNTEER AGREEMENT AFFIDAVIT:
ARL-HRED Local Adaptation of DA Form 5303-R. For use of this form, see AR 70-25 or AR 40-38

The proponent for this research is:	**U.S. Army Research Laboratory** **Human Research and Engineering Directorate** **Aberdeen Proving Ground, MD 21005**

Authority:	Privacy Act of 1974, 10 U.S.C. 3013, [Subject to the authority, direction, and control of the Secretary of Defense and subject to the provisions of chapter 6 of this title, the Secretary of the Army is responsible for, and has the authority necessary to conduct, all affairs of the Department of the Army, including the following functions: (4) Equipping (including research and development), 44 USC 3101 [The head of each Federal agency shall make and preserve records containing adequate and proper documentation of the organization, functions, policies, decisions, procedures, and essential transactions of the agency and designed to furnish the information necessary to protect the legal and financial rights of the Government and of persons directly affected by the agency's activities]
Principal purpose:	To document voluntary participation in the Research program.
Routine Uses:	The SSN and home address will be used for identification and locating purposes. Information derived from the project will be used for documentation, adjudication of claims, and mandatory reporting of medical conditions as required by law. Information may be furnished to Federal, State, and local agencies.
Disclosure:	The furnishing of your SSN and home address is mandatory and necessary to provide identification and to contact you if future information indicates that your health may be adversely affected. Failure to provide the information may preclude your voluntary participation in this data collection.

Part A • Volunteer agreement affidavit for subjects in approved Department of Army research projects

Note: Volunteers are authorized medical care for any injury or disease that is the direct result of participating in this project (under the provisions of AR 40-38 and AR 70-25).

Title of Research Project:	The Effect of Visually-Presented Workload Stimuli on Soldier Shooting Performance	
Human Use Protocol Log # Number:	**ARL-20098-**	
Principal Investigator:	David Scribner	Phone: 410-278-5983 E-Mail: dscribne@arl.army.mil
Associate Investigator(s)	Patrick Wiley	Phone: 410-278-5994 E-Mail: pwiley@arl.army.mil
	William Harper	Phone: 410-278-5955 E-Mail: bharper@arl.army.mil
Location of Research:	Aberdeen Proving Ground, MD	
Dates of Participation:		

Part B • To be completed by the Principal Investigator

Note: Instruction for elements of the informed consent provided as detailed explanation in accordance with Appendix C, AR 40-38 or AR 70-25.

Purpose of the Research

You are invited to participate in a study designed to evaluate the effects of realism (simulated versus live-fire) on shooting. More specifically, the purpose of this study is to compare shooting performance data collected under both simulated and live-fire conditions. This study will be conducted at the Army Research Laboratory (ARL) – Human Research Engineering Directorate (HRED).

Procedures

Participation in this study will require a one-day visit to both the shooting simulation laboratory and M-range, live-fire facility. On that day, you will be asked to (1) provide written informed consent to participate in the study, (2) be assigned a confidential participant ID number, (3) complete a demographics questionnaire, (4) choose whether or not to provide the principle investigator your ASVAB score, (5) be tested for visual acuity and color vision, and (6) a) zero both a real M16A2 rifle and a M16A2 simulated weapon using M-Range and the Dismounted Infantryman Survivability and Lethality Testbed (DISALT) shooting simulator, shoot 3, 18-target pop-up scenarios for training, and then shoot 10, 18-target pop-up scenarios. Prior to collecting the research data, you will see a range safety briefing video in accordance with AR40-63, paragraph 2-C.

You will be asked to (1) complete a set of pre-test questionnaires including the Subjective Rating of Events (SRE), and the Subjective Workload Assessment Tool (SWAT) and (2) complete two questionnaires (SRE, SWAT) between each experimental shooting-task condition.

Each condition, for both siumulated and live-fire scenarios, will consist of 18 pop-up target presentations (trials) distributed across various distances, locations, and exposure times. The target type presentations will be enemy targets consisting of equal sized solid green silhouettes. The target exposure times will vary between 2, 3, and 5 seconds. Targets are always to be fired upon.

This will require approximately 4 hours in all.

You may not be eligible to participate in this study if: (1) your shooting eye visual acuity is less than 20/30 when corrected with glasses or contact lenses or you if are color blind, (2) your medical profile indicates that your health status requires approval by your physician.

Benefits

You will receive no benefits from participating in the project, other than the personal satisfaction of supporting research efforts to better understand factors that affect differences in live fire versus simulated fire shooting scenarios.

Risks

Risks associated with this evaluation are minimal and are less than those encountered by Soldiers during their normal field training exercises or by civilians at a public or private shooting range. Standard safety procedures will be followed for simulated weapon use.

Members of the test administration staff will be close to you throughout all evaluation trials to assist you should a problem arise. If you ask to terminate the test, care will be taken to minimize risks. If the WBGT equals or exceeds 85°F testing will be halted. You will have a break of at least 5 minutes between shooting-task conditions.

Confidentiality

All data and information obtained about you will be considered privileged and held in confidence. Photographic or video images of you taken during this data collection will not be identified with any of your personal information

(name, rank, or status). Complete confidentiality cannot be promised, particularly if you are a military service member, because information bearing on your health may be required to be reported to appropriate medical or command authorities. In addition, applicable regulations note the possibility that the U.S. Army Medical Research and Materiel Command (MRMC-RCQ) officials may inspect the records.

Disposition of Volunteer Agreement Affidavit

The Principal Investigator will retain the original signed Volunteer Agreement Affidavit and forward a photocopy of it to the Chair of the Human Use Committee after the data collection. The Principal Investigator will provide a copy of the signed and initialed Affidavit to you.

Obtaining of ASVAB Scores

IF YOU ARE AN ACTIVE DUTY ENLISTED MILITARY VOLUNTEER, we would like to obtain your Armed Services Vocational Aptitude Battery (ASVAB) scores for potential data analysis. The ASVAB scores would be used strictly for research purposes. The results of any such analyses would be presented for the group of participants as a whole; and no names will be used. With your permission, we will obtain these scores by sending a copy of this signed consent form along with your Social Security Number to the Defense Manpower Data Center (DMDC) in Seaside, CA where ASVAB scores may be obtained from their databases in Arlington, VA or Seaside, CA. If you do not wish your ASVAB scores to be released to the principal investigator, you will still be allowed to participate in the research.

If you would like to participate in this research, please sign one of the following statements, and then complete the information requested at the end of this form:

I **DO AUTHORIZE** you to obtain my ASVAB scores. ______________________________
(Your Signature)

I **DO NOT AUTHORIZE** you to obtain my ASVAB scores. ______________________________
(Your Signature)

Contacts for Additional Assistance

If you have questions concerning your rights on research-related injury, or if you have any complaints about your treatment while participating in this research, you can contact:

Chair, Human Use Committee
U.S. Army Research Laboratory
Human Research and Engineering Directorate
Aberdeen Proving Ground, MD 21005
(410) 278-5919 or (DSN) 298-5919

OR

Office of the Chief Counsel
U.S. Army Research Laboratory
2800 Powder Mill Road
Adelphi, MD 20783-1197
(301) 394-1070 or (DSN) 290-1070

I do hereby volunteer to participate in the research project described in this document. I have full capacity to consent and have attained my 18th birthday. The implications of my voluntary participation, duration, and purpose of the research project, the methods and means by which it is to be conducted, and the inconveniences and hazards that may reasonably be expected have been explained to me. I have been given an opportunity to ask questions concerning this research project. Any such questions were answered to my full and complete satisfaction. Should any further questions arise concerning my rights or project related injury, I may contact the **ARL-HRED Human Use Committee Chairperson at Aberdeen Proving Ground, Maryland, USA by telephone at 410-278-5919 or DSN 298-5919.** I understand that any published data will not reveal my identity. If I choose not to participate, or later wish to withdraw from any portion of it, I may do so without penalty. I understand that military personnel are not subject to punishment under the Uniform Code of Military Justice for choosing not to take part as human volunteers and that no administrative sanctions can be given me for choosing not to participate. I may at any time during the course of the project revoke my consent and withdraw without penalty or loss of benefits. However, I may be required (military volunteer) or requested (civilian volunteer) to undergo certain examinations if, in the opinion of an attending physician, such examinations are necessary for my health and well being.

<table>
<tr><td colspan="2">Printed Name of Volunteer (First, MI., Last)</td></tr>
<tr><td>Social Security Number (SSN)</td><td rowspan="2">Permanent Address of Volunteer</td></tr>
<tr><td>Date of Birth
(Month, Day, Year)</td></tr>
<tr><td>Today’s Date
(Month, Day, Year)</td><td>Signature of Volunteer</td></tr>
<tr><td colspan="2">Signature of Administrator</td></tr>
</table>

Appendix B. Demographic Data Form

DEMOGRAPHICS AND EXPERIENCE QUESTIONNAIRE

Subject Number ______________

Age_____ Height ___ ft ___ in Weight _____lbs

Rank______ Date entered military (month)_______ (year)______

Primary MOS______ Secondary MOS______

1. When was the last time you qualified with the M16A2 rifle?

______ Month _____ Year

2. What is your current level of qualification as a rifleman based on the Army's or Marine's standard?

____expert ____sharpshooter ____marksman

3. Do you usually fire a rifle ____left handed or ____right handed? (Check one)

4. Do you use your ____left eye or ____right eye to aim a weapon?

5. Do you wear glasses or contact lenses when you shoot? ___ Yes ___ No (Check one)

6. Do you play video games or computer games?

____Yes   ____No

7. How well do you play video games?
____Poor   ____Below Average   ____Average   ____Above Average   ____Excellent

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Appendix C. SWAT Event Rating Form

SUBJECTIVE WORKLOAD ASSESSMENT TECHNIQUE

SUBJECT ID________________________ TASK ID__________________________

(Mark an X in one choice for each of the three areas below that best describes what you believe the task workload to be.)

TIME LOAD

1 Often have spare time. Interruptions or overlap among activities occur infrequently or not at all.

2 Occasionally have spare time. Interruptions or overlap among activities occur frequently.

3 Almost never have spare time. Interruptions or overlap among activities are frequent, or occur all the time.

MENTAL EFFORT

1 Very little conscious mental effort or concentration required. Activity is almost automatic requiring little or no attention.

2 Moderate conscious mental effort or concentration required. Complexity of activity is moderately high due to uncertainty, unpredictability, or unfamiliarity. Considerable attention required.

3 Extensive mental effort or concentration are necessary. Very complex activity requiring total attention.

PSYCHOLOGICAL STRESS

1 Little consusion, frustration or anxiety exists and can be easily accommodated.

2 Moderate stress due to confusion frustration or anxiety. Noticeably adds to workload. Significant compensation is required to maintain adequate performance.

3 High to very intense stress due to confusion frustration or anxiety. High to extreme determination and self-control required.

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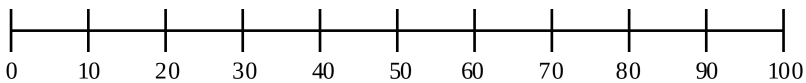
Appendix D. Subjective Rating of Events (SRE) Form

SUBJECT ID: ______________________ TASK ID: ___________________

1. The scale below represents a range of how stressful an event might be. Put an "X" on the line to rate how much stress you experienced <u>during the previous experimental trial?.</u>

Not at All Stressful

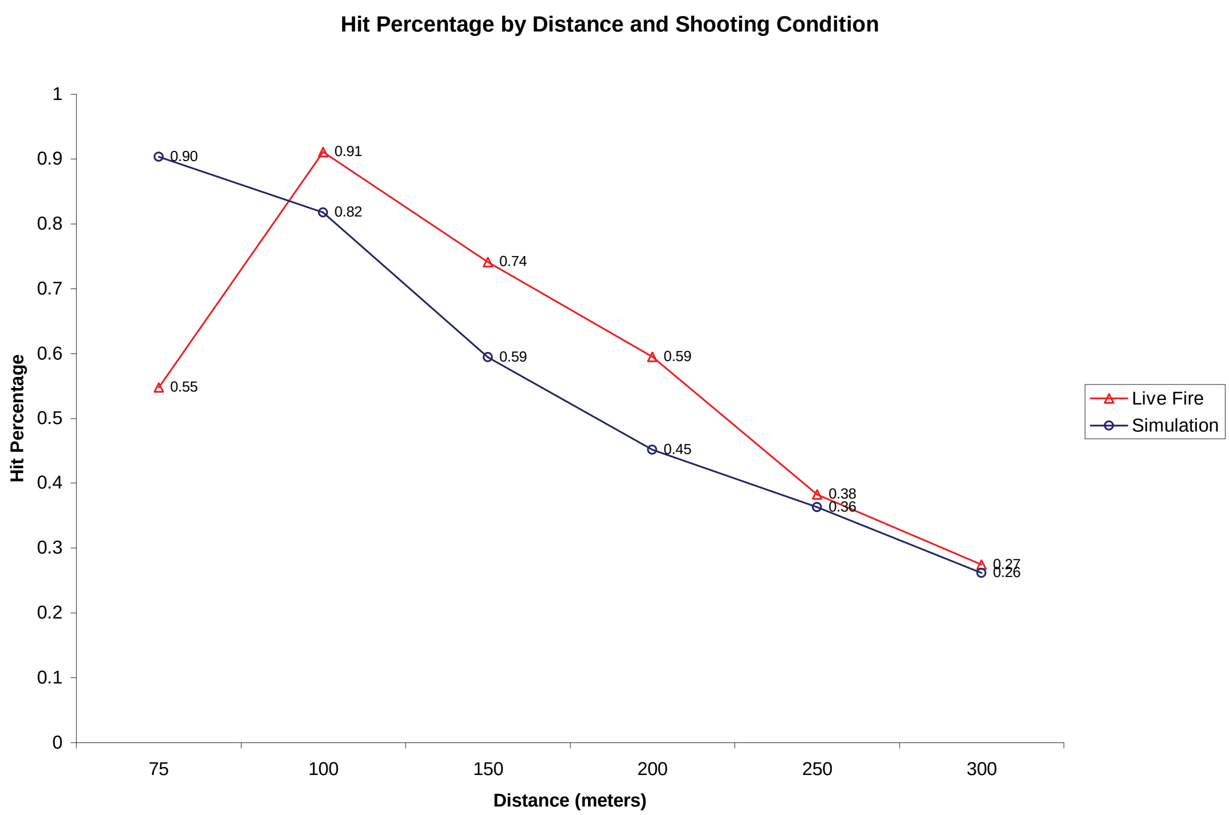
Most Stress Possible



2. At what number value does the "X" touch the line? ________

INTENTIONALLY LEFT BLANK

Appendix E. Hit Percentage Means by Target Distance



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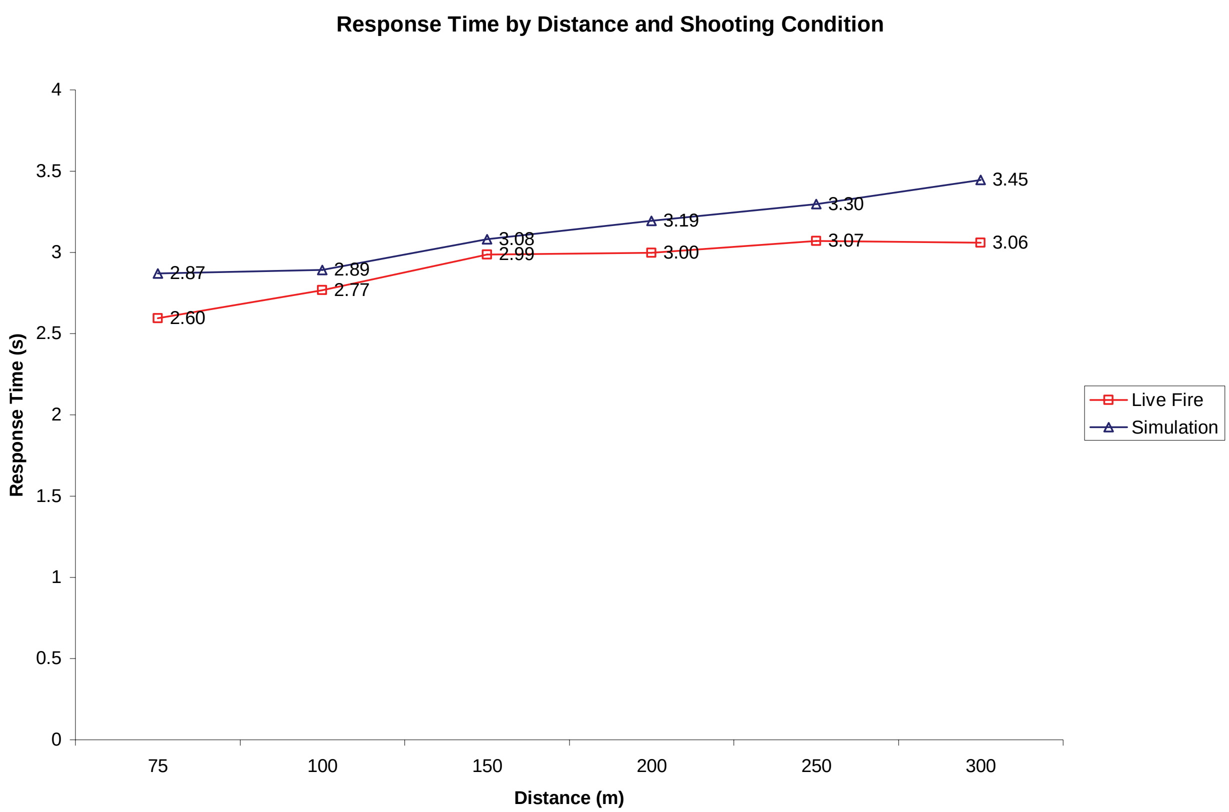
Appendix F. Shot Reaction Time Means by Target Distance



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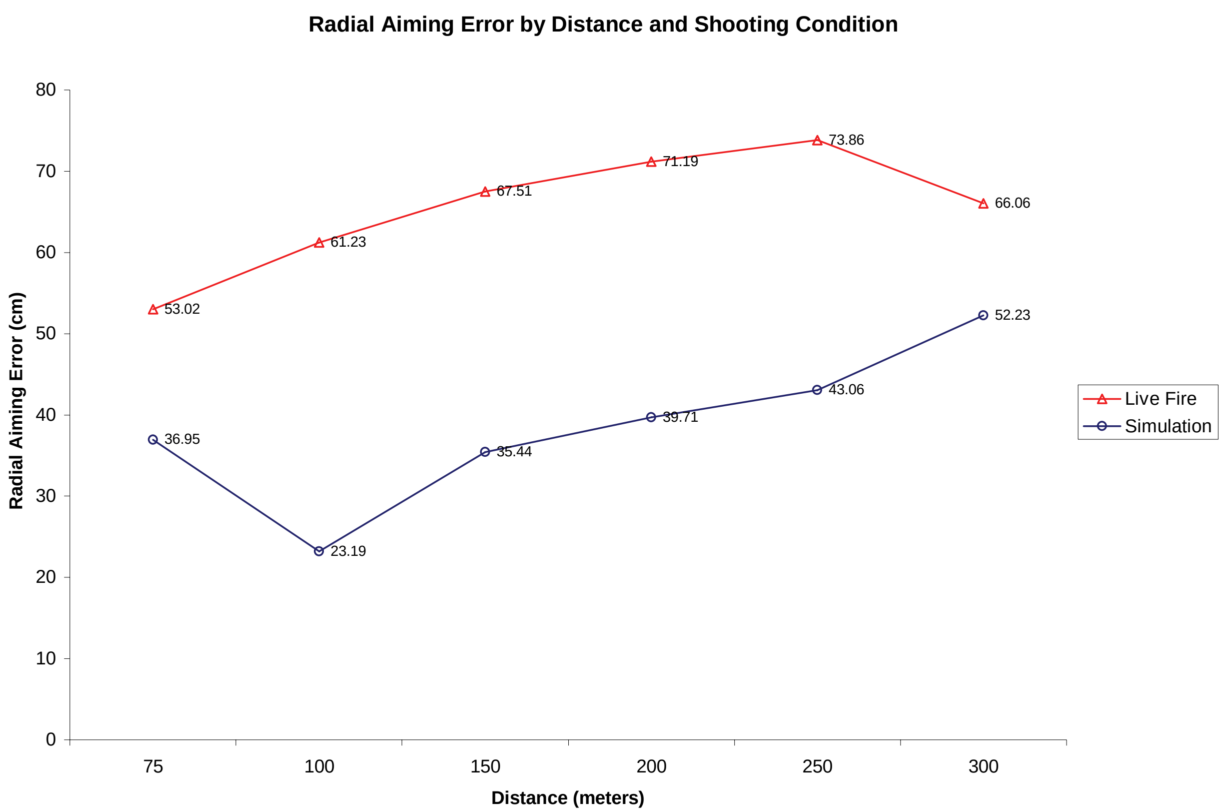
Appendix G. Radial Aiming Error Means by Target Distance



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